TITLE

DOOR SUSPENSION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a door suspension system and, in particular, to an elevator car door suspension system.

The European patent application No. 0 841 286 A1 discloses an elevator car door suspension system for opening and closing elevator car doors including a linear induction motor having a pair of movable motor primaries attached to a respective door hanger of each door and a stationary motor secondary attached to a header bracket which is secured to the elevator car, and wherein the motor secondary comprises a substantially flat plate which is vertically disposed and is preferably made of a conductive metal as copper. In this system, in which the door panels are guided by separate rails, a pair of moving flexible ropes and wheels is needed to the panels moving synchronously.

A problem with an elevator car door suspension system having moving flexible ropes and wheels is that it is very expensive. Another drawback is due to stability and maintenance problems.

SUMMARY OF THE INVENTION

The present invention concerns an apparatus for suspending doors such as elevator car doors.

An object of the present invention is to provide an improved door suspension system.

One of the advantages of the door suspension system according to the present invention is that it can be easily and inexpensively manufactured and easily and quickly installed.

DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

Fig. 1 is a schematic sectional view of a door suspension system for an elevator car according to a first embodiment of the present invention;

Fig. 2 is a fragmentary front elevation view of the door suspension system shown in Fig. 1;

Fig. 3 is a fragmentary perspective view of the door suspension system shown in Fig. 1;

Fig. 4 is a simplified perspective view of a bearing located between a rail and a bracket of the door suspension system shown in Fig. 1;

Fig. 5 is a sectional view of a panel door with an upper hinge joint and a lower guiding joint according to the present invention;

Fig. 6 is a schematic illustration of a structure of a magnetic track of a second embodiment of the present invention;

Fig. 7 is a schematic illustration of a primary of the linear motor of the second embodiment of the present invention;

Fig. 8 is a schematic illustration of a structure of a magnetic track of a third embodiment of the present invention; and

Fig. 9 is a schematic illustration of a primary of a linear motor of the third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The door suspension system shown in Fig. 1 includes a rail support **1** attached to a crosspiece **2** of a door frame and disposed above the doorway or entrance portal. The system may be applied to doors, windows, opening portions as doorways of industrial buildings, houses, elevator cars, vehicles and the like. Preferably, the rail support **1** has a T-profile or an L-profile. In the position shown in Fig. 1, the T-profile is turned counterclockwise at an angle of 90° degrees. The horizontal part of the rail support **1** is a rigid substantially flat plate **3** which supports a linear rail **4**, e.g. of a commercially available type, extending at least approximately the length of the door or having approximately the same length as the required door travel. The rail **4** has a substantially cylindrical head body **5** and supported by a vertical web **6** with horizontal extensions **7** attached to the plate **3**. An example of a linear rail is the Thomson rail system currently used in certain industrial linear motion applications and available from Thomson

Industries, Inc. of Port Washington, New York. The door suspension system includes a bracket **8** including a connector **9** joined to a support block **10** having a recess or opening **11**, in which the cylindrical body **5** with a part of the web **6** is introduced. The connector **9** has a substantially C-profile embracing the flat plate **3** with the linear rail **4**. Attached to the outer lower surface of the bottom of the connector **9** there is a support strip or piece **12** with a connection means **13** from which a door or door panel **14** is suspended as seen in Fig. 2. The connection means **13** preferably include screws or other types of fastener for attaching the door panel **14**.

The rail support **1** can be connected with the crosspiece **2** with connecting means **30**, for instance a screw, a bolt or a nut. Between the connecting means **30** and the support block **10** there is a gap, so that the support block **10** can move freely.

As shown in Fig. 3, the bracket **8** is attached to an end area of the strip **12**, and the system includes a second bracket **8'** (Figs. 2 and 3) attached to the other end area of the strip **12**. There is positioned in the space between the brackets **8** and **8'** an elongated primary **15** (Fig. 1) of a linear motor, which preferably is a permanent magnet flat linear synchronous motor (PM-FLSM). Under the rail or in the flat plate **3** (FIG. 1) a magnetic way **16** is mounted which has at least approximately the same length as the required door travel. Such magnetic way **16** may be a magnetic track using magnets, which may be rare earth permanent magnets, such as neodymium-iron-boron (NdFeB), cobalt, samarium or cheap hard permanent ferrite magnets disposed with alternating magnetic polarities. As shown in Fig. 1, the flat plate **3** has recesses **17** for receiving the magnet assemblies of the magnetic way **16**.

The brackets **8** and **8'** each also have a bearing or a bushing **18**, like a linear plain bushing or a linear ball bushing, located in the air gap of the support block **10** between the body **5** and the inner border of the recess **11**. As seen in Fig. 4, the bushing **18** may be a substantially cylindrical ring-shaped body with a hole **19** for the body **5** and a longitudinal opening **20** for the web **6**. Preferably, the bushing **18** is made from a sliding synthetic material, for example plastic material such as the "iglide J" bearing available from igus, inc. of E. Providence, Rhode Island, or the Thomson "FluoroNyliner" bearing, or a linear ball bushing, for example of the Thomson "Super Smart" type. When the motor is active, the bushings **18** slide along the body **5**.

Fig. 5 illustrates a door panel with an upper hinge joint **21** and a lower guiding joint **22**. Since, as seen in Fig. 3, the linear motor primary **15** is attached to the door or door panel **14** via the brackets **8** and **8'**, both will be moved together.

The linear motor is disposed in such a way that the attraction force between the magnetic way **16** and the primary **15** cancels at least partially the weight of the door or door panel **14**. This reduces considerably the radial force applied to the bearings or bushings **18** as well as the overall friction in the system and the maximum required force of the motor. This semi-active magnetic suspension allows the door to open faster and noise-less, the motor and the inverter to be smaller in size and the life of the linear bearings to increase substantially due to the load reduction.

Due to the relatively high attraction between the magnetic way **16** and the primary **15** it is convenient to use a very rigid guiding system so that no deflection and change in the air gap dimension can occur. This requirement is fulfilled by the linear rail system and the high stiffness of the brackets **8** and **8'**. In order to accelerate the motion of the door, the primary current must be increased, which in turn increases the attraction force in the air gap, another reason why the rigidity of the system must be high.

Referring now to Fig. 6, another embodiment of a magnetic way is shown, in which the flat plate **3** is not provided with a recess for each magnet system, but magnets **23** are attached to a strip or back iron **24** which in turn is attached under the flat plate **3** as seen in Fig. 7, wherein a primary **25** is located over a strip **12'**. Figs. 8 and 9 show still another embodiment of the magnetic way, which is similar to the embodiment of Fig. 7 in that there are magnets **26** attached to a separate strip or back iron **27**, but different from the embodiment of Figs. 6 and 7 in that the strip **27** is attached over the support strip **12'**. Accordingly, a primary **28** may be secured to the flat plate **3** under the same.

Other advantages of the system according to the present invention are that a high reliability can be achieved due to the great reduction in the number of parts in comparison with the prior art systems and the use of nearly maintenance-free components; also the volume of the motor and a suitable inverter can be reduced; extra heat generated in the primary can be avoided; no extra bearings are needed to keep the motor air gap constant, avoiding so stability and maintenance problems; and additional ropes and wheels are not needed.

The magnets **23** or **26** are disposed with alternating polarity on the surface of the strip **24** or **27**, respectively, which may be a back iron with segments (not shown) intermediate to inset-mounted permanent magnets. The width of the intermediate segments may be smaller than that of the permanent magnets. Preferably, the back irons **24** and **27** with or without segments are formed from a soft magnetic material such as mild steel, preferably having a relative permeability $\mu_r >> 1$. Accordingly, each sequence of magnetic elements **23** or **26** includes a flat permanent magnet with the **N** polarity above, an optional intermediate magnetic element, a flat permanent magnet with the **S** polarity above and an optional intermediate magnetic element. The intermediate magnetic elements may be flat elements of mild iron or steel, plates of ferrite, preferably but not exclusively soft ferrite. The magnets **23** and **26** and/or other optional intermediate elements may be glued to the back iron. The primary and the magnetic way are separated by an air gap **L**, e.g. of 1 to 2.5 mm. The air gap **L** can be adjusted by varying the thickness of suitable shims **29** (Fig. 1). The position control may comprise sensors according to the prior art or any other standard linear positioning devices. Note that there is a direct relationship between the door panel mass, the air gap **L**, the attraction force, and the required tractive force.

Although an open linear guide is disclosed, a closed linear guide or block **10** is also possible for this door suspension system. In a simplified embodiment of the invention without a motor, the primary may be replaced by a simple back iron. If the guide means **10** and **10'** are made from a sliding synthetic material, for example the Igus with IglidurJ plastic material, the bearings **18** may be eliminated, and in this case the diameter of the opening **11** should be smaller, specifically, it must fit the rail or other equivalent element **4**. Generally speaking, the guide means may or may not include the bearing **18**.

It is an advantage of the present invention, that the use of a PM synchronous motor combined with a hall effect sensor achieves a very precise absolute positioning of the door panels as well as a re-initialization if needed.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.